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Agricultural Adaptation to Climate Change: How Risk Influences Decision-Making

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Agricultural Adaptation to Climate Change:

How Risk Influences Decision-Making

by

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Abstract

Climate change is currently threatening the livelihoods of farmers in developing countries. Psychological models have been developed to identify factors associated with adapting to climate change; however, little work has investigated the role of farmers' risk attitudes in these models. We assessed perceptions of adaptation cost and adaptation intentions for five drought-specific adaptive behaviors among 550 farmers from 12 villages in the dry zone of Sri Lanka, as well as their attitudes toward risk. Results suggest that perceived adaptation cost and risk attitude are negatively associated with adaptation intentions. The conditional effect of adaptation cost on adaptation intention as a function of risk attitude was also investigated. Results showed that only farmers with risk averse attitudes were impacted by their perceptions of adaptation costs. These findings have implications for those interested in increasing adaptive practices of farmers in developing countries who face increasingly scarce water supplies.

Keywords: climate change, agricultural adaptation, risk, drought, protection motivation theory, decision-making

Agricultural Adaptation to Climate Change:

How Risk Influences Decision Making

Agriculture is the most prominent industry in the world. Thirty-eight percent of Earth's land is used for agricultural purposes, with crop production alone accounting for 1.5 billion hectares (FAO-STAT, 2013). Agriculture also accounts for more than 70% of all fresh water use in the world and approximately 325 billion kilowatts of energy per year, which is 58 billion kilowatts more than the entire country of Portugal (Enerdata, 2014; FAO, 2015). Even with these massive amounts of resources devoted to agriculture, 793 million people in the world are undernourished, the majority of whom live in developing countries (FAO, 2015). The world's population is expected to grow from 7.4 billion to 12.5 billion from now to the end of the 21st century, with the same developing countries that currently possess the most inadequate food supplies accounting for the highest rates of population growth; making food shortages in these regions an even larger problem (UN, 2015). Solving this problem through the expansion of agriculture is highly unlikely because of the insufficient supply of land that is both suitable for agriculture and not under environmental protection (FAO, 2015).

The prosperity of agriculture in developing countries is important for reasons other than food production. On average, agriculture accounts for 29% of GDP and 65% of employment in developing countries (The World Bank, 2008). Agriculture also plays a predominant role in the industrialization of these countries (De Souza, 2015). Climate change, which will be felt most strongly in developing countries (Mendelsohn, Dinar, & Williams, 2006), threatens to disrupt the productivity of agriculture, and therefore threatens the economic development of these nations.

Anthropogenic climate change is expected to have many negative impacts on agriculture. Global temperatures are expected to rise 1.8 – 4.0°C by the end of the 21st century (Parry, Canziani, Palutikof, Linden, & Hanson, 2007). This increase in temperature will result in larger amounts of pest damage, less efficient use of soil nutrients, and smaller crop yields (Fuhrer, 2003). Climate change will most significantly impact agriculture through a diminishing supply of fresh water: a 2°C increase in global temperatures can negatively affect water accessibility for 3 billion people (Panjabi, 2014); global sea levels are expected to rise 210 – 830mm (IPCC, 2013), which will cause freshwater irrigation supplies near coastal regions to become salinized (Forster et al., 2011); 30% of land will be in an extreme drought by the end of the 21st century (Burke, Brown, & Christidis, 2006); and the amount of rainfall in many developing regions is expected to decrease and become unpredictable (De Silva, Weatherhead, Knox, & Rodriguez-Diaz, 2007; Eriyagama & Smakhtin, 2009; Mertz, Mbow, Reenberg, & Diouf, 2009; Thomas, Twyman, Osbahr, & Hewitson, 2007).

Morton (2007) identifies smallholder farmers within developing countries as the most vulnerable population in regards to climate change. These farmers rely on small-scale farming, driven primarily by family labor, as their main source of income. The majority of these farmers' fields are located in arid climates and utilize minor irrigation systems (rain-fed tanks), rather than major irrigation systems that are not dependent on rainfall (Zarebski, 2012), making them even more susceptible to the water shortages that are expected to become more frequent. It is vital that these farmers develop an understanding of the changing climate and adopt new agricultural practices that will be effective in adapting to increasingly scarce water supplies.

Climate Change Adaptation

Climate change adaptation can be defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007, p. 6). These adjustments can occur within multiple dimensions – *proactive* or *reactive* and *private* or *public* (Grothmann & Patt, 2005; Klein et al., 2007; Reser & Swim, 2011; Smit & Skinner, 2002). Proactive adaptation refers to actions that are taken in preparation for expected climatic stimuli while reactive adaptation refers to responses to climatic stimuli that are currently occurring or have already occurred. Private adaptation refers to changes that occur at the individual level while public adaptation refers to community-level responses.

There are multiple methods of agricultural adaptation (Anwar, Liu, Macadam, & Kelly, 2012; Hisali, Birungi, & Buyinza, 2011), which can be sorted into four main categories (Smit & Skinner, 2002). *Technological developments* refer to advancements in agricultural tools such as new irrigation systems, weather information systems, and genetically modified crops that are more tolerant to extreme conditions. *Government programs and insurance* include providing farmers with crop insurance to reduce the financial impacts of climatic stimuli, implementing resource management programs that educate farmers how to use scarce resources in times of extreme climate conditions, and providing incentives for farmers to change their farming practices according to the climate. *Farm production practices* include farmers planting different crops that may be more efficient in certain types of climates, changing the time they plant, and making use of irrigation systems. *Financial management* includes diversifying household income, purchasing crop insurance, and participating in income stabilization programs. This research focuses on the category of farm production practices. Whereas other categories focus on providing the tools, information, and motivation to adapt, or minimizing the financial losses that would result from climate change, farm production practices focus on the actual acts of adaptation taken by farmers. In most cases, however, these categories are interdependent of each other; for instance, the actions taken by farmers to adapt to climate change may depend on the incentives or information provided by government programs.

The majority of farmers are aware of the changing climate, however, there are many barriers that prevent them from adapting. Economic constraints prevent farmers from purchasing adaptive tools such as efficient irrigation systems (Below et al., 2012; Below, Schmid, & Sieber, 2015; Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Esham & Garforth, 2013). A lack of information regarding adaptation strategies inhibits proper responses to climate change (Anwar et al., 2012; Deressa et al., 2009; Esham & Garforth, 2013). Certain demographic variables such as gender and low education are associated with lower rates of adaptation (Below et al., 2012; Deressa et al., 2009; Fisher & Carr, 2015). Further, shortage of time and labor prevents farmers from adjusting their farming practices in accordance with the changing climate (Deressa et al., 2009; Esham & Garforth, 2013; Thomas et al., 2007).

Many socio-economic solutions to these barriers have been suggested. An increase in farmers' access to credit has been shown to be related to an increase in adaptation rates (Deressa et al., 2009). Providing farmers with proper information and technology is expected to increase adaptive responses to climate change (Anwar et al., 2012; Below et al., 2012, 2015; Esham & Garforth, 2013). Additionally, increasing the quality of education available may also improve adaptation rates (Below et al., 2012).

Psychological Factors

Although the previously mentioned barriers are important to address for improving farmers' responses to climate change, the potential for psychological factors regarding adaptation to act as barriers to adaptation has been gaining interest. If farmers acted as "rational actors", then with all of the necessary resources, they would do whatever would produce the largest benefit; however, McFadden (1999) explains that rationality is rare in human nature, and instead individuals' decision-making processes are not only influenced by the utility of their choices, but by many cognitive anomalies as well. Kahneman and Tversky's (1979) well established prospect theory explains that when individuals consider the probability of an event occurring, they will weigh the potential for a loss greater than the potential for a gain. Applying this theory in the context of climate change adaptation suggests that if an adaptive agricultural practice has a small probability of producing a negative outcome and a large probability of producing a positive outcome, a farmer may weigh these probabilities equally. Decision-making can be influenced by omission bias, which explains that individuals prefer to incur a cost that results from inaction rather than incurring a cost that results from taking action (Baron, 1992; Ritov & Baron, 1990, 1995). This explains how farmers may rather be negatively affected by climate change than be objected to a small chance of self-harm that may occur from taking action to adapt. Samuelson and Zeckhauser (1988) established that, when faced with a decision, individuals will often decide on the choice that best fits with the status quo, which may explain why social networks, culture, and traditions play an important role in farmers adaptation decisions (Below et al., 2012; Esham & Garforth, 2013; Gifford, 2011; Osbahr, Twyman, Adger, & Thomas, 2010; Truelove, Carrico, & Thabrew, 2015).

Much psychological research regarding climate change adaptation has used protection motivation theory (PMT) as a foundation (Grothmann & Patt, 2005; Grothmann & Reusswig, 2006; Keshavarz & Karami, 2016; Reser & Swim, 2011; Truelove et al., 2015). PMT, which was originally developed to study decision-making regarding health behaviors, has two main factors: *threat appraisal* and *coping appraisal* (Floyd, Prentice-Dunn, & Rogers, 2000; Milne, 2000). The threat appraisal process occurs first and involves analyzing the *severity* of the potential threat and the *vulnerability* of the individual. Coping appraisal occurs once a threat has been appraised and involves three sub-components: *response efficacy, self-efficacy, and response costs.* Response efficacy represents perceptions of how effective an adaptive behavior will be. Self-efficacy is an individuals' perceived ability to engage in the behavior. Response costs include any perceived costs or risks (i.e., financial, temporal, and social) that are associated with engaging in the behavior. All of these perceptions have the potential to be affected by the previously mentioned cognitive biases (McFadden, 1999; Patt & Schroter, 2008; Suarez & Patt, 2004).

Grothmann and Patt (2005) took these cognitive biases, as well as other factors that are important in predicting adaptation, into account when they created a model of private proactive adaptation to climate change (MPPACC) based off of PMT. In the MPPACC, Grothmann and Patt label threat appraisal as "risk appraisal," and within this factor they replaced perceptions of vulnerability with *perceived probability*, which represents the probability that an individual will be exposed to a threat. This model also refers to coping appraisal as "adaptation appraisal," response efficacy as "perceived adaptation efficacy," and response costs as "perceived adaptation costs." Additionally this model includes factors of *adaptation incentives, reliance on public adaptation, cognitive biases, objective adaptive capacity*, and *risk experience appraisal*. Objective adaptive capacity refers to individuals' perceived accessibility to resources, knowledge, and social networks that may influence their adaptation appraisal. Risk experience appraisal is included in this model to account for the potential effect of the availability heuristic on individuals' risk appraisals. The availability heuristic explains that individuals' knowledge and experiences of previous events will influence their perceptions of the probability and severity of future events (Suarez & Patt, 2004). This implies that an individual who has recently experienced only minor damage from a moderate drought will perceive future droughts as similar in severity and may therefore choose not to adapt.

Research involving this model and other PMT-based cognitive models provide more accurate predictions of adaptation intentions than socio-economic models (Grothmann & Patt, 2005; Grothmann & Reusswig, 2006; Truelove et al., 2015). Research also shows that the construct of adaptation appraisal is typically a much stronger predictor of adaptation intentions than risk appraisal (Floyd et al., 2000; Grothmann & Patt, 2005; Grothmann & Reusswig, 2006; Milne, 2000). Further, based off prospect theory and omission bias, one could expect that, within the component of adaptation appraisal, perceived adaptation costs would have a larger effect size than perceived adaptation efficacy and self-efficacy; however, the strength of these sub-components are often inconsistent. In one meta-analysis, using PMT to predict health behavior, perceived adaptation costs was found to be the most influential (Floyd et al., 2000). Another meta-analysis of PMT found self-efficacy to have the most robust effect on adaptive behavior (Milne, 2000). In a study investigating the predictive power of a socio-psychological model on adaptation intentions, adaptation efficacy was found to be the strongest predictor of adaptation intentions (Truelove et al., 2015). These inconsistencies in effect size may be due to an unaccounted moderating variable. One potential variable, which these models fail to include, is individuals' attitudes toward risk.

Risk Attitude

Risk attitude can be defined as "the chosen reflection or response of individuals or organizations toward risk in terms of potential hazard, threat, or monetary loss at a judged probability" (Ye & Wang, 2013, p. 861). Attitudes toward risk have been shown to be an important factor in many decision-making processes, including farmers' decisions to engage in adaptive agricultural practices (Binswanger, 1980; Dillon & Scandizzo, 2001; Jianjun, Yiwei, Xiaomin, & Nam, 2015; Liu, 2013; Ye & Wang, 2013).

There are two methods typically used to measure risk attitudes (Dohmen et al., 2011; Jianjun et al., 2015; Pennings & Smidts, 2000). The first employs questionnaires to obtain information regarding personal traits and tendencies that are related to risk taking behaviors (Hansson & Lagerkvist, 2012). The second method is more direct and relies on expected utility theory to assess risk preferences by having participants make multiple decisions regarding options of monetary payouts with varying degrees of probabilities and amounts. This second method is most often implemented (Binswanger, 1980; Dillon & Scandizzo, 1978; Jianjun et al., 2015; Liu, 2013); however, it represents risk attitudes in a strictly financial domain. This is a problem considering Weber, Blais, and Betz's (2002) discovery that risk attitudes are domain specific; that is, an individual can be risk averse regarding their social interactions but risk seeking in their financial decisions. Research on risk attitudes should consider the domains of risk included in the behavior of interest in order to obtain the most accurate assessment.

Engaging in adaptive agricultural practices often involves multiple domains of risk (e.g., financial, social, and temporal; Esham & Garforth, 2013; Gifford, 2011) and because of this, farmers' risk attitudes may be most accurately captured by implementing questionnaires that are framed in a farming context. However, most research on this topic relies on responses to lottery scenarios and expected utility theory (Binswanger, 1980; Dillon & Scandizzo, 1978; Jianjun et al., 2015; Liu, 2013), which may assess only the financial aspects of farming. Although these studies lack diversity in their assessment techniques, they demonstrate that farmers are primarily risk averse or risk neutral (Binswanger, 1980; Dillon & Scandizzo, 1978; Jianjun et al., 2015; Liu, 2013; Ye & Wang, 2013) and that increased risk aversion is related with low rates of adaptation (Jianjun et al., 2015; Liu, 2013). However, one study that also implemented a gambling scenario to measure risk attitude discovered that increased risk aversion is related with higher rates of adaptation. (Jain, Naeem, Orlove, Modi, & DeFries, 2015). There is a need for more research on this topic that utilizes methods other than expected utility theory to assess risk attitudes. There is also a lack of research regarding the potential interaction between farmers' perceptions of adaptation costs and their risk attitudes.

Objectives

The purpose of this research is to investigate the effects of perceived adaptation cost and risk attitude on farmers' intentions to adopt several drought-specific adaptive agricultural practices. The following hypotheses are predicted and visualized in a hypothetical model (Fig. 1):

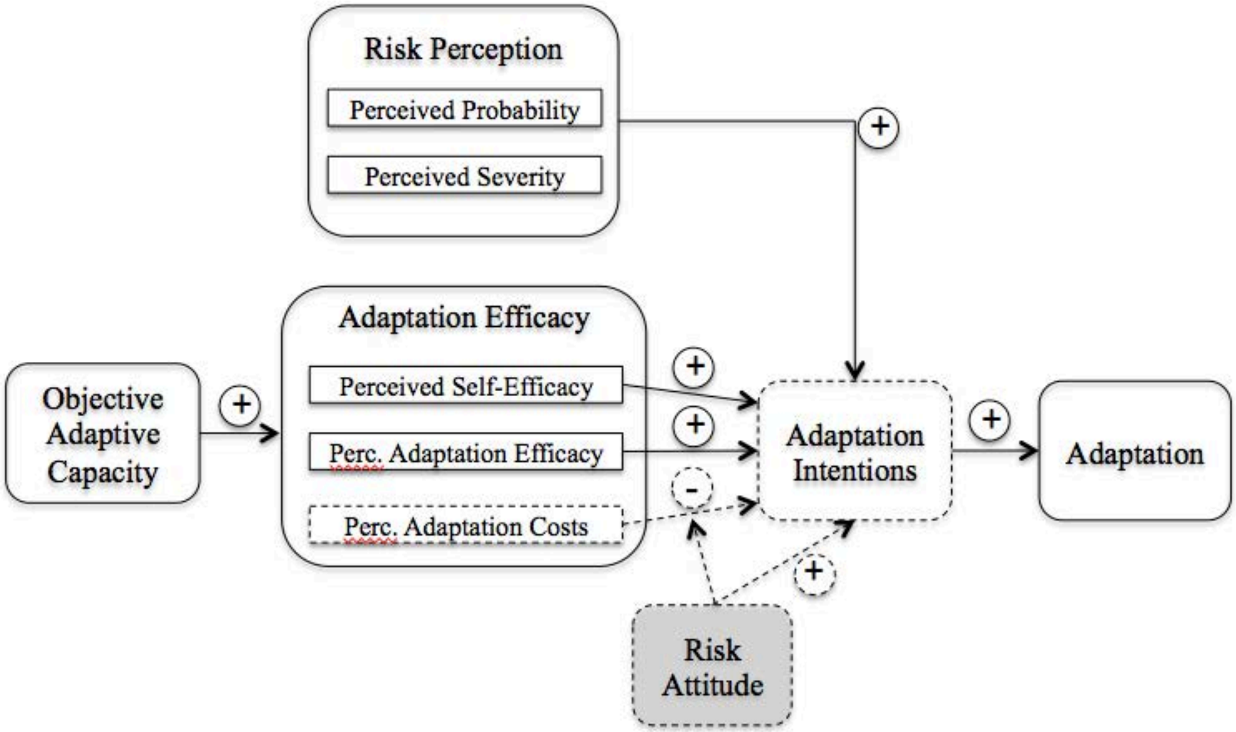
H1. Farmers' perceptions of adaptation costs will be negatively associated with adaptation intentions. This hypothesis is anticipated because of much previous research demonstrating a clear negative effect of adaptation costs on adaptation intentions (Grothmann & Patt, 2005; Grothmann & Reusswig, 2006; Keshavarz & Karami, 2016; Milne, 2000).

H2. Farmers' risk attitudes will be positively associated with adaptation intentions; that is, farmers who show greater preference for risk will be more likely to intend to practice the behaviors. This association is expected based on previous research that has shown risk aversion to be negatively associated with adaptation (Jianjun et al., 2015; Liu, 2013).

H3. The effect of farmers' perceptions of adaptation costs on adaptation intentions will depend on their level of risk attitude. Farmers with greater preference for risk will be less affected by their perceptions of adaptation costs than farmers with less preference for risk. This moderation effect is suggested by the inconsistent importance of adaptation costs in PMT-based models

(Floyd et al., 2000; Grothmann & Reusswig, 2006; Keshavarz & Karami, 2016; Milne, 2000) and the potential relationship between risk attitude and perceived risk (Weber et al., 2002).

Fig 1. Hypothetical model structured based on MPPACC (Grothman & Patt, 2005).



Note: Variables and relationships denoted by dashed lines are the primary focus of this research and represent the hypotheses stated above. Risk attitude, highlighted grey, is an additional variable not included in the original MPPACC.

Methods

Study Area

This research was conducted in the island nation of Sri Lanka, located off the coast of India. This country is particularly vulnerable to climate change because it is a tropical Asian island (Mendelsohn et al., 2006; Petzold & Ratter, 2015). Although the economy of Sri Lanka has recently been expanding in the service and industry sectors, agriculture still accounts for 11% of the nation's GDP and 31% of employment (Central Bank of Sri Lanka, 2014), with rice being the primary subsistence crop. Approximately 11% of all land in Sri Lanka is devoted to growing paddy (Department of Census and Statistics Sri Lanka, 2015), which produces more than 3.5 million metric tons of rice, none of which is exported (Central Bank of Sri Lanka, 2014). Unfortunately, rice is extremely sensitive to adverse weather conditions: a .5°C increase in temperature can lead to a 6% decrease in rice yield (Eriyagama & Smakhtin, 2009); 1,432 liters of water are required to grow 1 kg of rice (International Rice Research Institute, 2013); and paddy, at the flowering stage, can incur damage if exposed to temperatures over 35°C (Eriyagama, Smakhtin, Chandrapala, & Fernando, 2010).

Sri Lanka has two major paddy cultivation seasons: Maha (October to March) and Yala (April to September; Esham & Garforth, 2013). Approximately 72% of paddy is grown during the Maha season (Eriyagama et al., 2010); however, this season is expected to face many challenges because of climate change: irrigation water requirements are expected to increase 13-23% by 2050 (De Silva et al., 2007); rainfall is expected to decrease 26-34% (Eriyagama & Smakhtin, 2009); and temperatures are predicted to increase as much as 2.9°C (Eriyagama & Smakhtin, 2009). Based on these seasonal climate predictions, a growing population (United Nations, 2015), and the expansion of hydropower (Eriyagama & Smakhtin, 2009), it appears that the main climate change-related challenge that Sri Lanka will face is potential water shortages.

Sri Lanka is comprised of three climatic zones: the wet zone, the intermediate zone, and the dry zone. For comparison, the dry zone typically receives 800-1200mm of rainfall per year, while the wet zone receives more than 2000mm (De Silva et al., 2007). The dry zone encapsulates more than half of Sri Lanka's total land mass and accounts for 72% of the country's rice production (De Silva et al., 2007). This already water stressed dry zone is expected to face the most difficult challenges of climate change (De Silva et al., 2007; Eriyagama et al., 2010;

Eriyagama & Smakhtin, 2009). Based on Sri Lanka's high degree of vulnerability to climate change, its economic reliance on agriculture, the sensitivity of its primary subsistence crop, and the large role of the dry zone in growing paddy, climate change is expected to have a severe impact on this nation's paddy production.

The Mahaweli River Development Program is an attempt to solve the problem of water scarcity in the dry zone in Sri Lanka. The Mahaweli Development Program consists of diverting the Mahaweli River, Sri Lanka's largest river, through regions of the dry zone to provide farmers in this area with a larger and more reliable supply of water for irrigation. The development program covers nearly 40% of Sri Lanka, and includes 18 communal systems, which are home to more than 160,000 families (Mahaweli Authority of Sri Lanka, 2013). However, many farmers in the dry zone still do not have access to this major irrigation network and instead rely on small village tank systems, typically referred to as *purana* or traditional systems, that are highly dependent on rainfall (Esham & Garforth, 2013).

Sampling

The data used for this research represent the first cohort of a large, multidisciplinary, NSF-funded research project on climate change adaptation among farmers in Sri Lanka (NSF grant # EAR-1204685). A total of 30 villages in Sri Lanka's dry zone were identified for this project; six were allocated to a pilot cohort, 12 were assigned to this first cohort, and the remaining 12 were assigned to a second cohort.

The selection process consisted of first, identifying districts, the largest administrative unit in Sri Lanka, that are entirely or primarily located in Sri Lanka's dry zone. Thirteen districts met this criterion and were stratified based on their geographic location (North, Central, and South). It was decided that 10 villages in the Northern region, 12 villages in the Central region, and 8 villages in the Southern region would be selected. These selection sizes were constructed in proportion to the size of the regions.

Each district is divided into sub-units called Divisional Secretariat (DS) divisions. The amount of DS divisions in a district can range from four to 23 depending on the district's size. The DS divisions of the 13 districts selected for this study were stratified based on their most prevalent irrigation system: mahaweli (major) or purana/traditional (minor). Twelve DS divisions were then selected at random based on this stratification: six DS divisions with major irrigation systems and six with minor irrigation systems. One Grama Niladhari (GN) division, the smallest administrative unit in Sri Lanka, was then selected at random from each DS.

A list of villages within each GN was created, excluding any villages that did not have the same type of irrigation system (i.e., major or minor), or majority religious group as the GN as a whole. One village per GN was then randomly selected.

After the villages in each GN had been selected the GN's voter list was used to generate a list of all households located within each village. The farm organization in each village was asked to identify any households on the list that did not farm paddy so that they could be removed. A targeted sample size was created for each village in proportion to the size of the village. Households were then selected at random until the targeted sample size was reached.

Random household selection for one of the 12 originally selected villages for this first cohort was not implemented and was replaced by a 13th village with similar characteristics. The final sample includes 550 farmers from 12 different villages. The number of households sampled in each village ranged from 35 to 80. Farmers ranged in age from 19 to 85 years old (M = 49.47, SD = 11.86) and were predominately male (90.4%). The most commonly practiced religion was

Buddhism (79.9%) and the most common ethnicity was Sinhalese (80%). The majority of farmers had a secondary education (49.1%) or below secondary education (26.9%).

Survey

A survey was created in collaboration with the National Building Research Organization (NBRO) of Sri Lanka and other local officials. The survey consisted of three sections and was carried out through face-to-face interviews that were conducted by Nielsen Research Sri Lanka, a research firm specializing in market research. The survey questions were written in English, translated into Sinhalese and back translated into English, and the participant responses were recorded in Sinhalese and then translated into English before data entry.

The first section of the survey involved interviewing the female head of household about various aspects of the home, including information regarding: individuals living in the household (e.g., age, gender, religion, etc.), construction of the household (e.g., ownership, when it was built, plumbing, etc.), assets of the household (e.g., TVs, cars, livestock, etc.), the primary source of drinking water (e.g., type of source, ownership, supply, etc.), access to medical care (e.g., location of treatment facility, frequency of injury, lack of needed treatment, etc.), family diet (rice, vegetables, fruits, etc.), method of coping with insecure food supplies (e.g., reduce number of meals, limit portion sizes, restrict consumption by adults, etc.), and overall health and well-being of only the responding female head. This interview took approximately one hour.

The second and third sections, which occurred on two different days, consisted of collecting farm related information from the head farmer, including: major farm challenges, access to farm equipment (e.g., tractor, combine harvester, storage, etc.), land ownership (e.g., amount of land, type of land, length of time farming the land, etc.), previous seasons' harvests (e.g., amount of land farmed, damage from climatic stimuli, amount of paddy harvested, etc.), satisfaction ratings of the village's farm organization, use of agricultural advisory services, perceived changes in the environment (i.e., temperature, rainfall, and frequency of drought), potential problems that would result from climate change, past drought experiences, aid received after past droughts, expected assistance in future droughts, and financial information (i.e., insurance, debt, and income).

Information of particular interest to this study that was obtained through these interviews, involve farmers' perceptions of nine drought-specific adaptive behaviors:

- *Dry seeding*: farmers plow their land at the first rain of the season and spread seeds at the second rain, rather than plowing at both the first and second rain, in order to make better use of the rainfall. This method conserves water and reduces labor, but may result in increased weeds because of the reduced amount of plowing and puddling (Tabbla, Bouman, Bhuiyan, Sibayan, & Sattar, 2002).
- *Planting other field crops (OFCs)*: planting crops besides paddy that are more drought tolerant (e.g., onions, millet, maize, etc.) can ease the stress of a low water supply; however, some of these crops are more costly than paddy, may be seen as untraditional, or may require additional labor (Grothmann & Patt, 2005).
- *Recycling irrigation water*: involves capturing and re-using drainage water. This method is an effective water management technique, but can be expensive and labor intensive to build.
- *Short-duration seed varieties*: farmers plant early yielding paddy varieties that can be harvested in less than 4 months, as opposed to the standard paddy variety that takes five months to mature. These short duration seeds may be more expensive than the standard seed (Samant, Mohanty, & Dhir, 2015).

- *Transplanted seedlings*: farmers first plant seeds in a nursery soil bed where water is more efficiently managed and the seedlings are protected from extreme temperatures. After three weeks, the seedlings are dug out of the nursery and are replanted in the paddy fields. Replanting can cause slower maturation rates because of a replanting shock (Wiangsamut, Mendoza, & Lafarge, 2006)
- *Parachute method*: farmers first plant seeds in specialized trays where each seed gets its own pod. The trays are stored in a nursery where water is more efficiently managed and the seedlings are protected from extreme temperatures. After the seedlings have matured, the pods are moved to the paddy fields by tossing them in the air and allowing them to fall on the field. This method requires less labor than transplanting and prevents replanting shock, but may generate lower yields (Awan, Ali, Safdar, Ahmad, & Akhtar, 2008).
- *Low flood depth irrigation*: paddy fields are maintained with a flood depth less than 3cm as opposed to a traditional flood depth of 5-10cm. This practice generates larger yields than other adaptive methods, but has a lower water productivity rating (Tabbla et al., 2002).
- *Alternate wetting and drying (AWD)*: farmers allow their fields to alternate between being flooded and being unsaturated, rather than being continuously flooded. The amount of time between each flooding period depends on weather, soil, and the growth stage of the paddy. This method reduces water inputs by 15-30%; however, weeds can become more intrusive. (Bouman, Lampayan, & Tuong, 2007).
- *System of rice intensification (SRI)*: involves transplanting seedlings with a large distance between each seedling in order to maximize root growth, while maintaining a low flood depth saturation, and weeding and fertilizing the field frequently. This method is very labor

intensive, but eliminates some drawbacks of previously mentioned practices resulting in larger yields (Selvaraju, 2013).

For each of these behaviors, farmers were asked a series of questions including: whether they had heard of the behavior before, whether they had ever practiced it, and whether it was effective. They were also asked if they intended to practice the behavior in the future (0 = no, 1 = yes), which represents our variable of adaptation intention. Lastly the farmers were asked how risky they considered the behavior to be (1 = not at all, 2 = a little, 3 = moderately, 4 = very), which represents our measure of perceived adaptation cost.

Data regarding farmers' risk attitudes were collected through a risk attitude portion of the survey. This section included four questions regarding farmers' actions in hypothetical farming situations (Table 1).

Table 1

Risk attitude survey items.

Risk Attitude Items	Response Options
Imagine a season in which there is not enough water for farming. Would you consider farming with the expectation of rainwater?	1 = Yes 2 = No
Imagine a season in which the Farming Organization or Irrigation dept/Mahaveli official recommends that you cultivate half of your land. How much of your land would you plant?	1 = None at all 2 = Less than half 3 = Half your land 4= More than half 5 = All of your land
Imagine a season in which the Farming Organization or Irrigation dept/Mahaveli official recommend a 3-month variety. What variety would you plant?	1 = 2.5 month 2 = 3 month 3 = 3.5 month 4 = 4 month
If you get to know about a seed variety that promises to improve yields, but is vulnerable to disease, flood, or drought; would you consider using it?	1 = Yes 2 = No

Results

Adaptation Costs and Intentions

Of the nine adaptation behaviors included in the survey, five were deemed unsuitable for further analysis. Parachute method, low flood depth irrigation, and SRI were excluded because of inadequate response sizes (Table 2). Also, AWD was excluded because of unequal responses regarding adaptation intentions. The responses for adaptation intentions and perceived adaptation costs for the remaining five behaviors were then averaged together to create a measure of adaptation intention and perceived adaptation cost for each farmer (Table 3).

Table 2

Perceived adaptation cost and adaptation intention frequencies and percent endorsement.

Behavior	Adaptation Intention		Perceived Adaptation Cost			
	Yes	No	Not at all	A little	Moderately	Very
Dry Seeding	286 (52%)	253 (46%)	89 (16%)	149 (27%)	181 (33%)	120 (22%)
OFCs	217 (39%)	238 (43%)	115 (21%)	172 (31%)	113 (21%)	55 (10%)
Recycle Irrigation Water	184 (33%)	208 (38%)	128 (23%)	117 (21%)	97 (18%)	50 (9%)
Short Duration Seed	390 (71%)	152 (28%)	205 (37%)	206 (37%)	110 (20%)	21 (4%)
Parachute Method	104 (19%)	162 (29%)	75 (14%)	115 (21%)	51 (9%)	25 (5%)

Transplanting	229 (42%)	303 (55%)	233 (42%)	159 (29%)	90 (16%)	50 (9%)
AWD	292 (53%)	59 (11%)	161 (29%)	121 (22%)	44 (8%)	25 (5%)
Low Flood Depth Irrigation	207 (38%)	77 (14%)	130 (24%)	88 (16%)	50 (9%)	16 (3%)
SRI	18 (3%)	35 (6%)	21 (4%)	10 (2%)	15 (3%)	7 (1%)

Table 3

Descriptive statistics.

Variables	*M* (*SD*)	Minimum	Maximum
Adaptation Intention	.58 (.30)	0	1
Perceived Adaptation Cost	2.11 (.65)	1	4
Risk Attitude	1.96 (.47)	1	3

Risk Attitude

Risk attitude is typically measured using an expected utility theory framework with lottery-based questionnaires (Binswanger, 1980; Dillon & Scandizzo, 1978; Jianjun et al., 2015; Liu, 2013); however, there is reason to believe that this direct measure only represents risk attitude in a financial domain (Hansson & Lagerkvist, 2012; Weber et al., 2002). A less often implemented assessment is the use of behavioral questionnaires that indirectly measure risk attitude (Hansson & Lagerkvist, 2012). Pennings and Smidts (2000) explain that there are advantages and disadvantages for each method of operationalization; because of this it may be best to attempt to merge both methods. Two of the four items originally included in the risk attitude portion of the survey were excluded based on their dichotomous nature, which fails to represent both assessment methods. The remaining two items (Table 4) were used to measure risk attitude based on their hybrid structure that seems to represent the domains of risk attitude relevant for farming, while maintaining the directness of expected utility theory by providing farmers with a most logical, utility maximizing, answer choice in the form of a collaborative opinion of experts, which has been relied on in previous decision-making research to generate rational decisions (Clayton, 1997). However, one concern of using these items to represent risk attitude is the possibility of the measure being confounded with how much a farmer trusts their farm organization’s recommendations. To absolve this concern, a measure of farm organization satisfaction was included as a control in the analysis.

The item’s response options were recoded (Table 4) such that both items had similar response scales and more equally distributed response sizes. The reliability of using these items as a measure of risk attitude was assessed using Cronbach’s alpha (a = .676). Seeing as these two items have a high degree of internal consistency, they were averaged together to represent the variable of risk attitude (Table 3). Although the items are ordinal in nature, using the mean is supported by the understanding that these two items represent an assessment of how much risk a farmer is willing to take regarding two farming decisions, and that the average of these two items provides information regarding how much risk a farmer is willing to take in their farming practices on average, which contains a high degree of meaning – a consideration which may be most important in choosing an aggregation method (Clason & Dormody, 1994).

In terms of expected utility theory, with regards to minimizing the risk of being affected by water scarcity and maximizing crop yield, a score of two on this measure (Table 4) is thought to represent a risk neutral disposition since the farmer is making the most "logical" decision by following the experts' recommendations, which should provide the most utility (largest crop yield with the smallest chance of being affected by water scarcity). Scores below two are thought to represent a risk-averse disposition based on the notion that the farmer is sacrificing a larger crop yield to gain greater certainty that they will not experience water scarcity. Finally, scores above two are thought to represent a risk-seeking disposition since they are increasing their risk of experiencing water scarcity in order to maximize their crop yield. The distribution of this variable indicates that very few farmers have a risk-seeking disposition, which is consistent with previous literature (Binswanger, 1980; Dillon & Scandizzo, 1978; Liu, 2013; Ye & Wang, 2013).

Table 4

Recoded risk attitude items.

Risk Attitude Items	Original Response Options	*Recoded Response Option*	*N*
Imagine a season in which the Farming Organization or Irrigation dept/Mahaveli official recommends that you cultivate half of your land. How much of your land would you plant?	1 = None 2 = Less than half	1 = risk averse	1 = 91 (17%)
	3 = Half your land	2 = risk neutral	2 = 396 (74%)
	4= More than half 5 = All of your land	3 = risk seeking	3 = 46 (8.6%)
Imagine a season in which the Farming Organization or Irrigation dept/Mahaveli official recommend a 3-month variety. What variety would you plant?	1 = 2.5 month	1 = risk averse	1 = 63 (12%)
	2 = 3 month	2 = risk neutral	2 = 436 (82%)
	3 = 3.5 month 4 = 4 month	3 = risk seeking	3 = 35 (6%)

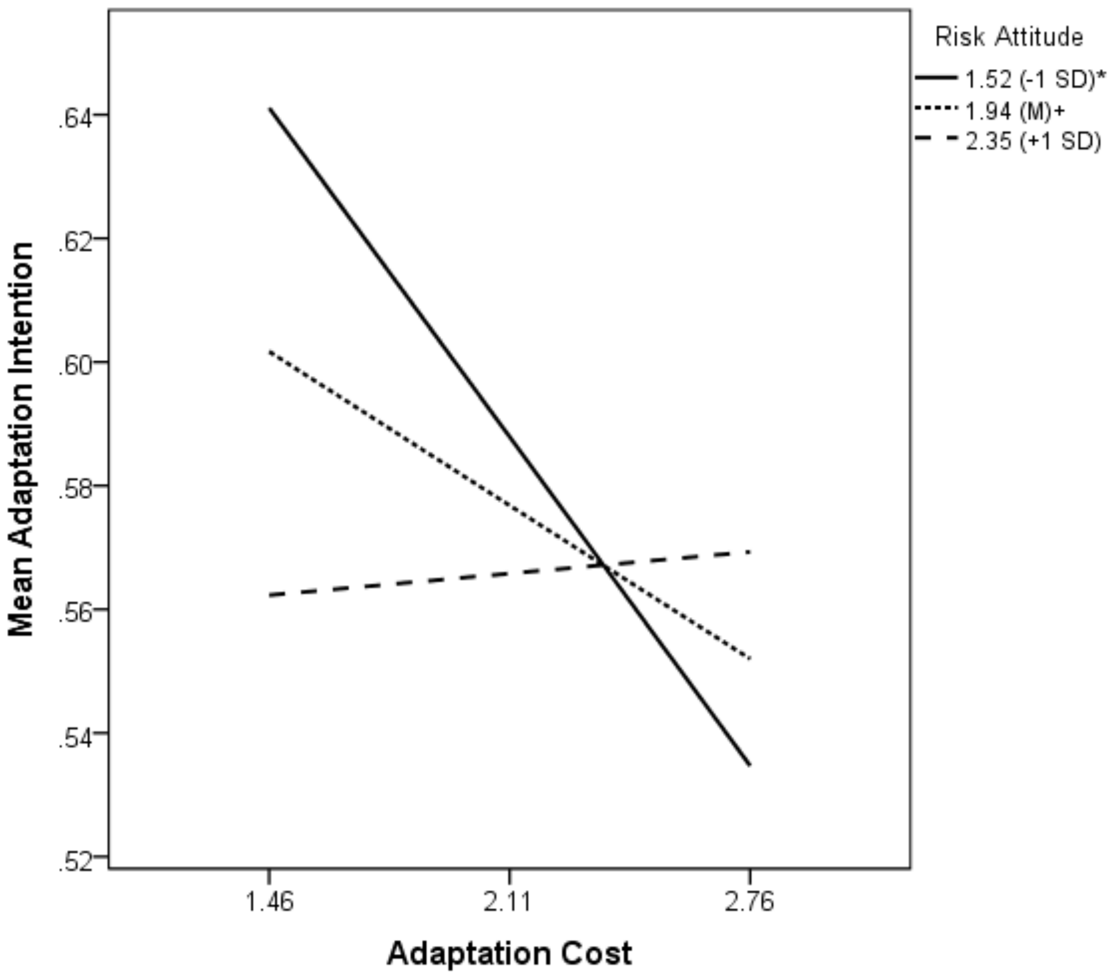
Conditional Process Analysis

A conditional process analysis was performed using the PROCESS macro for SPSS created by Andrew F. Hayes (2013), which enables the user to easily investigate moderation and mediation models. Heteroscedasticity consistent standard errors (HC3) were utilized to avoid concerns of violating the regression assumption of identically distributed residuals (Hayes, 2012, 2016; Long &Ervin, 1999). All other regression assumptions including linearity, normality, and multicollinearity were assessed and satisfied (Appendix A). The predictor variables were not centered based on literature suggesting its lack of purpose (Kromrey & Foster-Johnson, 1998).

Adaptation intention was entered as the dependent variable, perceived adaptation cost was entered as the independent variable, and risk attitude was entered as the moderating variable. The following variables were entered in the analysis as covariates: socio-economic status (SES), village, perceived impact of drought, perceived change in the frequency of drought, gender, and farm organization satisfaction. Controlling for these variables takes into account differences within the sample regarding the following: resources available to help farmers adapt (Deressa et al., 2009; Esham & Garforth, 2013), farmers' degree of vulnerability (Grothmann & Patt, 2005; Grothmann & Reusswig, 2006), and gender-based differences in adaptation intentions (Deressa et al., 2009; Fisher & Carr, 2015).

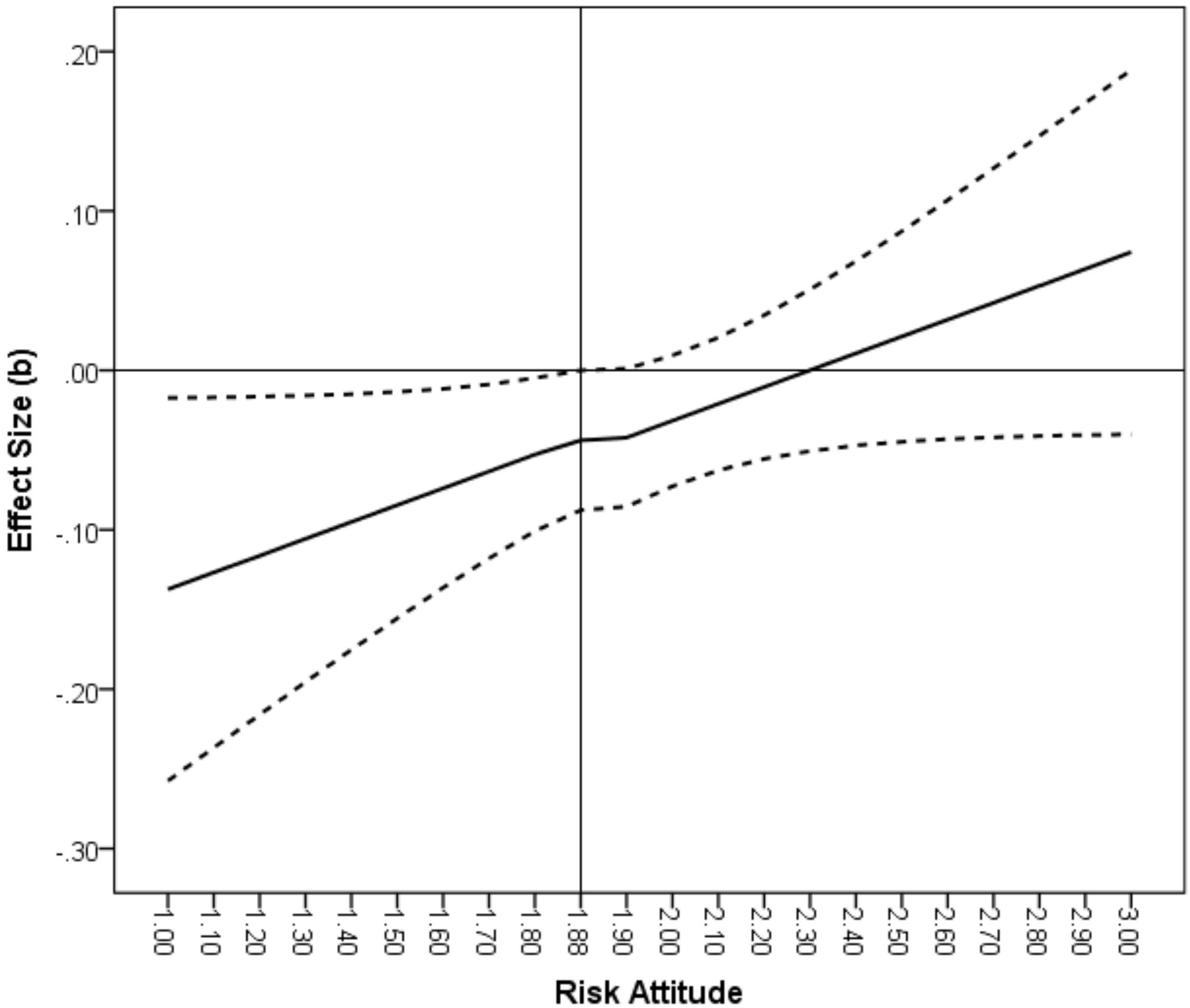
The analysis revealed the overall model to be significant, $F(23, 451) = 7.07$, $p < .001$, $R^2 = .25$. The association between adaptation cost and adaptation intentions was found to be significant, $t(451) = -2.11$, $b = -.24$, $p = .035$. A marginally significant main effect of risk attitude on adaptation intentions was also discovered, $t(451) = -1.90$, $b = -.25$, $p = .059$. The conditional effect of adaptation cost on adaptation intention as a function of risk attitude was marginally significant as well, $t(451) = 1.90$, $b = .11$, $p = .059$. The interaction was further probed by assessing the effect of adaptation cost on adaptation intention at various levels of risk attitude (*M* - 1 *SD*, *M*, and *M* + 1 *SD*; Fig. 2). This simple slopes analysis revealed that the negative effect of adaptation cost on adaptation intention is significant only for those with less favorable attitudes toward risk (*M* – 1 *SD*); $t(451) = -2.34$, $b = -.08$, $p = .020$. The Johnson-Neyman technique was also utilized to investigate the conditional effect. This analysis revealed the value of risk attitude at which the effect of adaptation cost on adaptation intentions becomes nonsignificant is 1.88, the effect for all values of risk attitude below this point are significant (Fig. 3).

Fig 2. Conditional effect of adaptation cost as a factor of risk attitude (simple slopes).



Note: + $p < .10$, * $p < .05$.

Fig 3. Conditional effect of adaptation cost as a factor of risk attitude (Johnson-Neyman).



Note: Dashed lines represent 95% confidence intervals. The displayed intersection marks the value of risk attitude (1.88) where the effect of adaptation cost on adaptation intention becomes nonsignificant ($p = .05$). Eighteen percent of farmers were to the left of this intersection and 82% were to the right.

Discussion

The results provide partial support for our hypotheses. Adaptation cost was negatively associated with adaptation intention, which supports Hypothesis 1 and is consistent with previous research (Grothmann & Patt, 2005; Grothmann & Reusswig, 2006; Keshavarz & Karami, 2016; Milne, 2000). This suggests that farmers are less likely to practice adaptive behaviors that they perceive as costly. There is a lack of empirical research on the variables that influence perceptions of adaptation costs in a farming context. However, there is literature on the topic of consumers' risk perceptions associated with purchasing products, which identifies objective knowledge of the product and monetary costs as two predictors of risk perceptions (Kaplan, Szybillo, & Jacoby, 1974; Klerck & Sweeny, 2007; Wildavsky & Dake, 1990). These variables of knowledge and financial concern also happen to be the most frequently reported barriers associated with not adapting to climate change (Deressa et al., 2009; Esham & Garforth, 2013) and may be contributing to farmers' perceptions of adaptation costs. More empirical research on this topic is needed, but the results suggest that providing farmers with accurate information about effective adaptive farming practices and financial assistance could lead to increased rates of adaptation (Deressa et al., 2009; Esham & Garforth, 2013; Hisali et al., 2011; Mertz et al., 2009).

Hypothesis 2 was not adequately supported. The effect of risk attitude on adaptation intention was only marginally significant; however, the negative effect seems to suggest that farmers who are more risk-averse are more likely to intend to practice adaptive farming behaviors. The direction of this association was unanticipated and inconsistent with some previous research, which demonstrates a positive relationship between risk attitude and adaptation intention (Jianjun et al., 2015; Liu, 2013); however, Jain et al. (2015) reported a negative association between these variables as well. When the effect of risk attitude on adaptation intention is discussed, it is often framed in terms of the action of engaging in a particular farming practice; that is, engaging in a farming practice may be associated with risk and this risk should deter farmers who are risk-averse; however, if the results are framed in the context of not adapting to climate change, which is inherently risky, and if farmers correctly identify this risk, those who are risk-averse should be more likely to attempt to minimize the risk by practicing adaptive behaviors. Thus, the effect of risk attitude on adaptation intention may be dependent upon which risk is more salient: the risk of engaging in an adaptive farming practice or the risk of not adapting to climate change. As mentioned above, one variable that seems to influence the degree of perceived risk associated with a behavior is the amount of objective knowledge a farmer has of that behavior. The studies that present differing effects of risk attitude seem to vary in regards to the amount of objective knowledge of the adaptive behavior being investigated; for instance, the research that offers evidence for a positive association between risk attitude and adaptation intention is in regards to less familiar adaptive behaviors (e.g., new technology; Jianjun et al., 2015; Liu, 2013), while the research that offers evidence for a negative association between these variables is in regards to more familiar behaviors (i.e., planting other crops, purchasing crop insurance; Jain et al., 2015; Jianjun et al., 2015). These inconsistent effects of risk attitude on adaptation intention suggest that further research is needed to identify potential moderating variables that may be influencing these effects in addition to perceived riskiness of the behavior; particularly the perceived risk of climate change.

Finally, this was the first study to investigate the potential conditional effect of adaptation cost on adaptation intention as a function of risk attitude. The result for Hypothesis 3 approached statistical significance levels; however, it seems apparent that the effect of adaptation cost on adaptation intention depends on a farmer's attitude towards risk. The simple slopes analysis revealed some interesting findings: farmers who are risk averse are significantly less likely to intend to practice adaptive behaviors as the perceived cost of those behaviors increases; farmers who are risk neutral also experience a negative association between perceived adaptation cost and adaptation intention, however this association is only marginally significant; and farmers who are risk seeking are not significantly affected by their perceptions of adaptation costs, but the association between these variables is trending in the positive direction. These results may suggest that farmers with less favorable attitudes towards risk weigh costs more heavily in their decision making process than farmers who are risk neutral or risk seeking. Further, the Johnson-Neyman technique used to investigate this conditional effect revealed that the vast majority of farmers in this sample were not significantly affected by their perceptions of adaption costs. This suggests that interventions with the purpose of reducing farmers' perceptions of adaptation costs might only be effective for a limited few. Hence, interventions may be most efficient if they assess risk attitudes prior to addressing perceptions of adaptation costs.

Limitations and Future Directions

One limitation of this research is the validity of its constructs. Only one item with four response options was used to assess farmers' perceived adaptation costs, which may be an inadequate explication of the construct. Although this item is thought to broadly represent the construct of adaptation cost it may be too general (Shadish, Cook, & Campbell, 2002). Also, giving participants an item with only four response options restricts the range of the construct and limits its' convergent validity; it has been suggested that the optimal number of responses for a Likert scale is 10 (Preston & Colman, 2000). However, this method was selected because of its appropriateness for lengthy face-to-face interviews, which required extensive translation.

Including additional items and response options throughout the three days of surveying would have led to fatigue and attrition. Future research may improve validity by implementing a single survey with multiple items designated to assess the multiple domains of adaptation cost (i.e., financial, social, temporal, etc.). Doing so would also allow researchers to provide a more accurate causal description for the relationship between adaptation cost and adaptation intention.

The operationalization of risk attitude used in this study strayed from the traditional method of assessment and requires improvement. One disadvantage of all behavioral questionnaire based approaches to measuring risk attitude, that was unable to be absolved in this study, is the influence of cognitive biases on participants' responses to items which rely on implied situations and outcomes. The construct may be more accurately assessed by clearly defining situations and probabilities of outcomes in a farming context. Also, a measure consisting of only two items with three response options may be insufficient in assessing the latent characteristics of risk attitude (Hansson & Lagerkvist, 2012; Preston & Colman, 2000); however, as mentioned above, this was appropriate because of the nature of the data collection process. Future research should attempt to develop a more direct, reliable, and domain inclusive measure of farmers' risk attitudes. Also, studies investigating the effect of risk attitude on adaptation intention have found inconsistent results (Jain et al., 2015; Jianjun et al., 2015; Liu, 2013), suggesting that further research is needed.

Although the focus of this research is specifically on developing a better understanding of risk in farmers' decision making processes, future research should also consider the conditional role of other variables such as self-efficacy and adaptation efficacy, both of which have been shown to have robust effects on adaptation intentions in previous research (Grothmann & Patt, 2005; Keshavarz & Karami, 2016; Truelove et al., 2015). The inclusion of these variables in future analyses may provide additional information about the complexity of farmers' adaptation decisions.

Conclusion

The primary goal of this research was to further investigate the role of risk in farmers' decision-making processes regarding agricultural adaptation to climate change. Risk attitude has been proven to be an important predictor of adaptation intentions (Jain et al., 2015; Jianjun et al., 2015; Liu, 2013), but has not been accounted for in PMT-based models. The results of this study suggest the presence of a conditional effect of perceived adaptation cost on adaptation intention as a function of risk attitude. Although PMT-based models are more accurate in assessing farmers' adaptation decisions than socio-economic models (Grothmann & Patt, 2005; Grothmann & Reusswig, 2006; Keshavarz & Karami, 2016; Reser & Swim, 2011; Truelove et al., 2015) this research demonstrates that including a measure of farmers' risk attitudes in these models can further increase the accuracy of their assessments. Using this research to build a more comprehensive model will provide a better understanding of the adaptation decisions of farmers and lead to more effective interventions aimed at improving farmers' responses to increasingly scarce water supplies.

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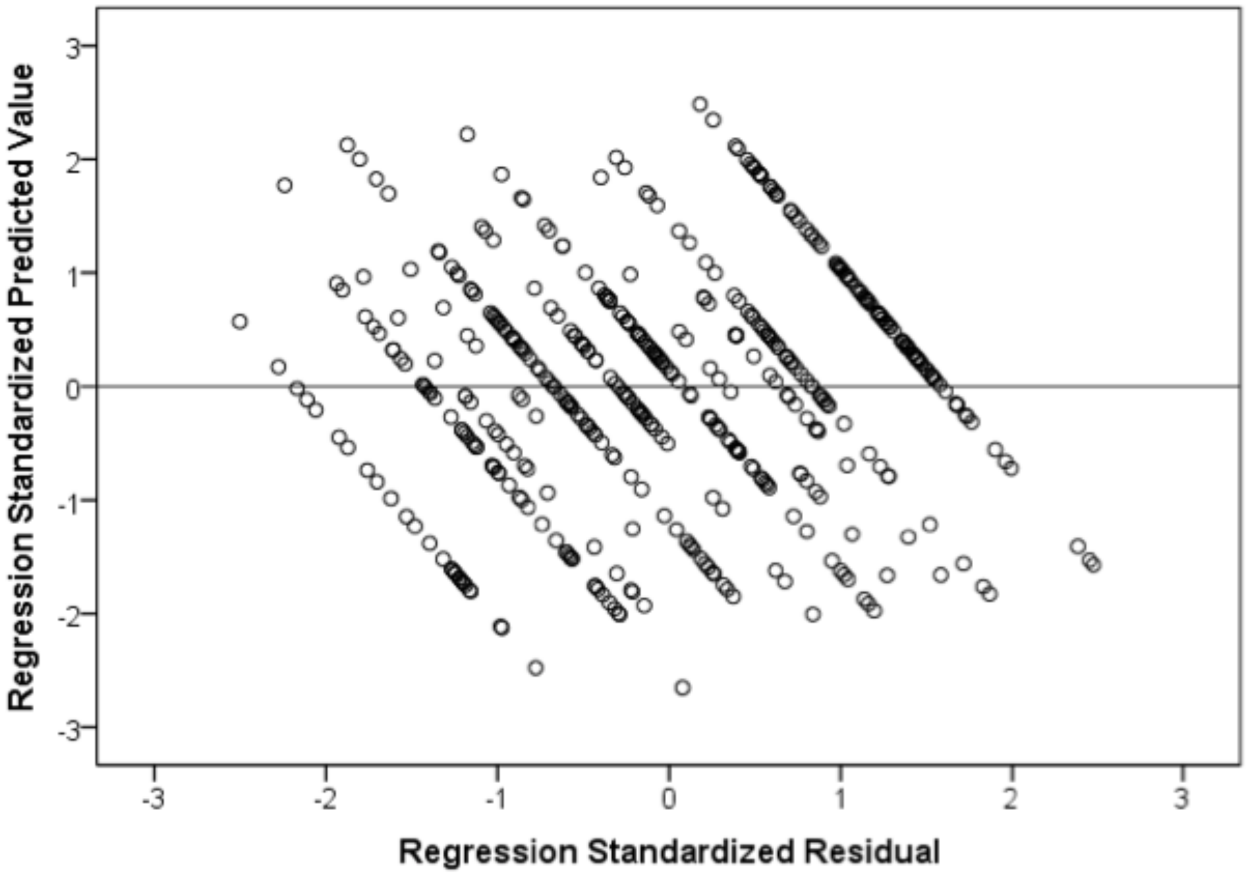
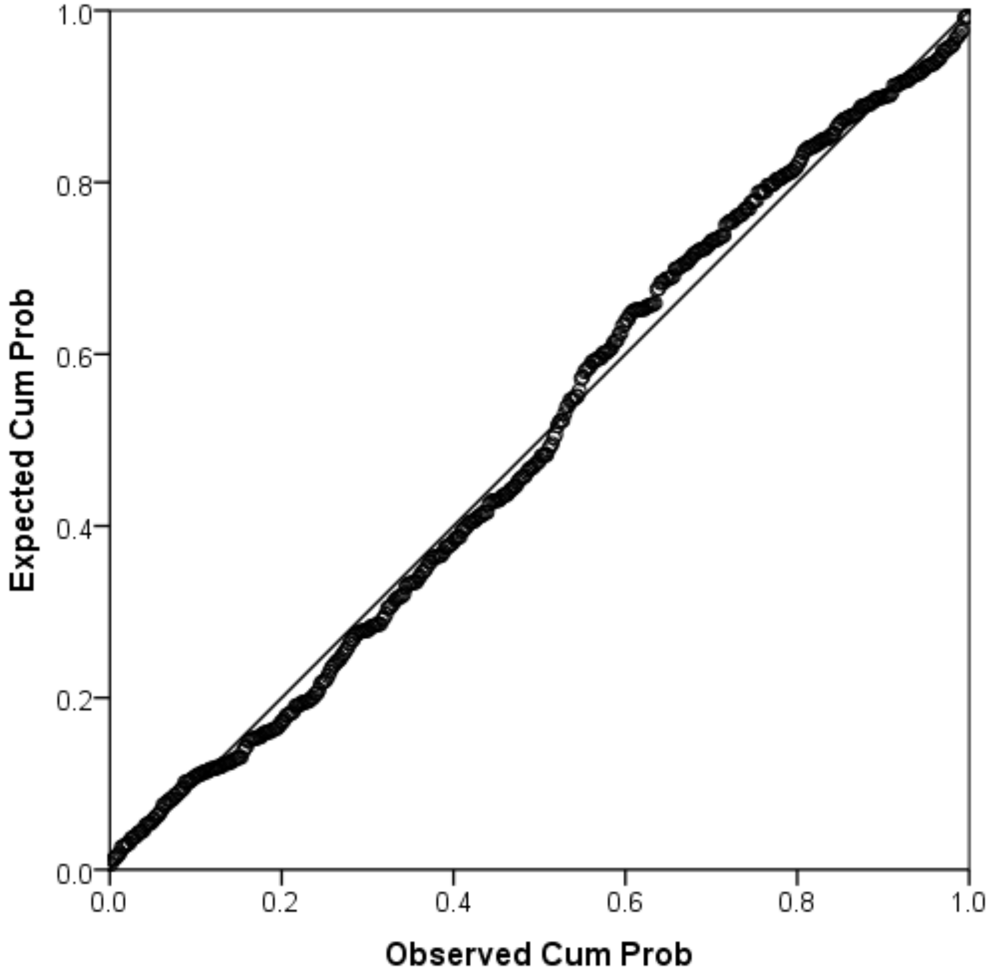
Appendix A

Statistical assumptions of linear regression

Linearity (Cohen, Cohen, West, & Aiken, 2013; Field, 2013)



Normal distribution of residuals



Multicollinearity

Variables	Tolerance	VIF
Perceived Adaptation Cost	.869	1.150
Risk Attitude	.506	1.975